8-1-2003

Efficacy of Herbicide Combination on Burley and Dark-Air Cured Tobacco

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EFFICACY OF HERBICIDE COMBINATIONS ON

BURLEY AND DARK-AIR CURED TOBACCO

A Thesis
Presented to
The Faculty of the Department of Agriculture
Western Kentucky University
Bowling Green, Kentucky

In Partial Fulfillment
Of the Requirements for the Degree
Masters of Science

By
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Fall 2003

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Date Recommended 4-27-04

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Dean, Graduate Studies and Research Date

Elmer Gray 4/29/04

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The efficacy of herbicide combination on burley and dark air-cured tobacco *Nictotiana tabacum* were tested in field research plots in the summer of 2000 at Western Kentucky University's Agricultural Research and Education Complex. The randomized complete block design contained six treatments replicated three times in each of the two experiments (burley and dark air-cured tobacco). Transplants (cv. 'TN 97' and cv. 'KY 160') were established on June 2, 2000 in a conventionally tilled Pembroke silt loam soil with a pH of 6.5 and organic matter content of 12 g/kg.

Herbicide treatments were applied on June 1, 2000 with a CO_2 backpack sprayer. Six treatments were applied to both burley and dark air-cured plots. Sulfentrazone was applied alone and in combination with either clomazone, pendimethalin, or napropamide. A sulfentrazone + clomazone combination followed by sethoxydim, as well as a clomazone + pendimethalin tank mix were also evaluated. Weeds targeted for control were: *Ipomoea hederacea* L. (ivyleaf morningglory), *Amaranthus hybridus* L. (smooth pigweed), and *Eleusine indica* L. (goosegrass).

Sulfentrazone alone provided >69% control of smooth pigweed and >89 % control of ivyleaf morningglory in burley and dark-air cured tobacco. At 21 days after treatment (DAT) the combinations of sulfentrazone/pendimethalin, sulfentrazone/clomazone/sethoxydim, and clomazone/pendimethalin gave better control of smooth pigweed in burley tobacco than did sulfentrazone/clomazone, but there were no differences between treatments at later evaluation dates. In dark-air cured tobacco, at 21 DAT sulfentrazone and the sulfentrazone/napropamide combination provided better control of smooth pigweed than did sulfentrazone/sethoxydim, but there were no differences between treatments at later evaluation dates. With respect to ivyleaf morningglory control, addition of herbicide combinations did not provide an advantage to sulfentrazone alone.

Goosegrass control in dark-air cured tobacco was > 85% at all DAT, and control was > 45% in the burley plot. Control of goosegrass in both types of tobacco was > 94% with the triple combination of sulfentrazone/clomazone and sethoxydim at all evaluation dates, yet all combinations provided >86% goosegrass control at all evaluation dates. Addition of herbicides to sulfentrazone, (with the exception of napropamide) provided an advantage to goosegrass control in burley tobacco.

CHAPTER I

INTRODUCTION

Burley and dark air cured tobaccos are important agronomic crops to Kentucky, Tennessee, and Virginia. Tobacco production comprises much of the agricultural economy, crop production and heritage for these states. The tobacco grown is used mainly in cigarette and snuff production (Snell, 1990).

Nictotiana tabacum is a member of the Solanaceae or nightshade family. There are 65 other species of *Nicotiana*, but only *Nicotiana tabacum* and *N. rustica* are grown commercially. Commercial tobacco production began in Virginia as early as 1612 with John Rolfe's first shipment of tobacco to England in 1613 and rapidly spread to other parts of the southern United States (Smiley, 1990).

Weed control is an important production practice that must be considered prior to transplanting. First, one should identify what problem weeds are present. Once these pests are identified, one must decide which herbicide or herbicide combinations will provide the most cost-effective control. Weed interference can lower leaf yield and quality, increase production costs, interfere with harvesting operations, and increase the spread of certain diseases. Even with currently registered chemical control products and combinations thereof, not all weeds can be controlled with one herbicide alone. Other weed management practices such as crop rotation, early weed root destruction, and cultivation can supplement a tobacco herbicide program (Yelverton, 1993).

With advancements in chemical weed control, many problem weeds can be effectively controlled with proper use of chemical control products. Sulfentrazone provides effective control of many annual dicot species that infest tobacco crops. It provides excellent control of broadleaves and sedges and gives good suppression of grasses. Sulfentrazone is a selective, soil applied herbicide that can be applied preemergence or shallow preplant incorporated. Sulfentrazone is readily absorbed by weed roots and shoots (C&P Press, 2001).

Clomazone provides effective control of grass weed species and control of certain broadleaf species. Clomazone can be applied preemergence, preplant incorporated or post transplant, (within 7 days of transplanting) (C&P Press, 2001).

Sethoxydim is a selective, postemergence herbicide for control of annual and perennial grass weeds in dicot crops. Sethoxydim is most effective when applied to actively growing 9-18 cm grasses (C&P Press, 2001).

Pendimethalin controls many annual grasses and certain broadleaf weeds as they germinate but does not control established weeds. Pendimethalin can be applied preplant incorporated and/or as a post transplant lay by application and is most effective when adequate rainfall or irrigation is received within 7 days after application (C&P Press, 2001).

Napropamide controls *Sorghum halepense* L. (seedling johnsongrass), *Panicum dichotomiflorum* (fall panicum), *Amaranthus retroflexus* (redroot pigweed) and *Amaranthus hybridus* (smooth pigweed). Napropamide is applied preemergence, preplant incorporated and/or as a post transplant application (C&P Press, 2001).

The objective of this experiment was to evaluate the efficacy and crop safety of herbicide combinations in burley and dark-air cured tobacco crops.

CHAPTER II

LITERATURE REVIEW

HISTORY

Before Christopher Columbus discovered the New World, Native Americans were smoking tobacco in pipes. When Columbus returned to Europe, he brought tobacco seeds, and European farmers began to grow the plant. The tobacco plant was used for a variety of medicinal purposes and to help people relax. Later in 1560, Jean Nicot, a French diplomat, introduced tobacco and its use to France. The genus name *Nicotiana* was derived from his name. In 1612 John Rolfe introduced tobacco production to the American colonies by bringing tobacco seeds from South America to Virginia (Palmer, 1998).

ECONOMIC IMPORTANCE

Kentucky is the largest producer of burley tobacco and the second largest producer of all tobaccos. Value of tobacco production generally exceeds $1 million annually for each of more than one hundred Kentucky counties. Kentucky's annual tobacco value averaged more than $800 million during 1990-1999, up considerably from $250 million/year during 1960-1969. Tobacco in 2000 accounted for 53% of Kentucky's crop receipts and 18.8% of Kentucky's total agricultural receipts, although production accounts for only 1% of the farmland in Kentucky (Snell, 1990). An acre of tobacco averages around $4000 gross returns at the farm level while contributing approximately $40,000 in federal, state and local tax revenue as a result of taxes on tobacco products.

Every $1million of additional tobacco production contributes a total of $3.6 million to the Kentucky economy through direct, indirect, and induced effects (Snell, 1990).

TYPES OF TOBACCO

Burley tobacco is produced in 14 states, but Kentucky and the 7 adjacent states are considered the Burley Belt. United States burley production is regulated by the national marketing quota system. The national marketing quota is defined by law as not more than 103% nor less than 97% of the total of (a) number of pounds domestic cigarette manufactures estimate they intend to purchase during the marketing year, (b) average annual quantity of burley exported from the U.S during the preceding three marketing years, and (c) amount the Secretary of Agriculture determines is necessary to increase or decrease the producer association inventory to reach the reserve stock level. Reserve stock level is the larger of 50 million lb or 15% of the national marketing quota. Leasing of quotas is permitted between producers within Kentucky counties. Burley is marketed via the warehouse system; however, with the recent introduction of contracting, burley tobacco marketing is changing (Snell, 1990).

Fire-cured tobacco is produced in Kentucky, Tennessee and Virginia, with Kentucky representing 45% of the United States dark fire-cured tobacco production. Snuff, plug-chewing tobacco and cigars utilize fire-cured tobacco in their production. Around 50% of total fire-cured products are dependent upon foreign exports. The Netherlands is the largest importer of United States fire-cured tobacco, buying approximately 75% of total U.S. exports. Dark fire-cured tobacco production is regulated by an acreage allotment, and producers can market all products grown on said allotment. There are two types of dark fire-cured tobacco produced in Kentucky, Types 22 (East Kentucky) and 23 (West Kentucky). Most dark fire-cured tobacco is marketed by direct farm sales (Smiley, 1990).

Dark air-cured tobacco is grown in Kentucky, Tennessee, Virginia and Indiana, yet Kentucky accounts for > 80% of United States production. Chewing tobacco and snuff are the primary uses of dark air-cured tobacco. Dark air-cured tobacco production is regulated by an acreage allotment, and producers can market all products grown on that allotment. The program provides for lease and transfer of allotments, yet leases and sales of dark air cured tobacco allotments are limited to transactions between allotment holders within the same county. There are two types of dark air-cured tobacco produced in Kentucky, Types 35 (One-sucker) and 36 (Green River). Most dark air-cured tobacco is marketed directly on farm (Smiley, 1990).

PRODUCTION PRACTICES

a. Field Selection and Preparation

Tobacco production begins with site selection and preparation. A field needs to be selected on the basis of good internal drainage, and a well-fertilized grass sod would provide good soil structure that tobacco roots would easily penetrate. After selecting a site, proper preparation is crucial to success of the crop. Crop rotation should be practiced to reduce fertilizer element build-up, reduce disease incidence, and reduce weed populations. Preparing fields for transplant of young seedlings is important to establish an adequate population of tobacco. If sod fields are used, the land should be moldboard plowed in winter; if small grain cover crop fields are used, they should be moldboard plowed in early spring. Disking and use of a heavy drag should be used to level and smooth the soil (Sims, 1990).

b. Fertilization

A soil test should be taken to ensure proper nutrient management. Nitrogen, phosphorus, potassium, a balance of micronutrients and proper soil pH are important in producing a high yielding crop. Nitrogen is an essential nutrient for high yield in tobacco production; however, over fertilization will increase vegetative growth but may decrease leaf quality, delay maturity, increase weed growth, reduce soil pH, and increase nitrosamine concentration (Fowlkes, et al., 1995). Nitrogen rates for tobacco crops differ depending on cropping history and an estimate of residual nitrogen in the soil. If the level of nitrogen is low, a rate of 281-338 kg N ha^{-1} (250-300 lbs. nitrogen/acre) is recommended; for medium, levels of 225-281 kg N ha^{-1} (200-250 lbs. nitrogen/acre) is recommended, and for high levels 169-225 kg N ha^{-1} (150-200 lbs. nitrogen/acre) is recommended. Phosphorus and potassium should be applied according to soil test. Soil pH affects plant availability of essential nutrients in the soil. A desirable soil pH for burley tobacco is 6.6; however a pH range of 5.6-6.0 is desirable for dark tobacco (Fowlkes, et al., 1995).

c. Transplant production

Due to extremely small seed size, seeding directly into the field is usually unsuccessful; therefore, transplant production is necessary. Currently, the majority of transplants are grown in a greenhouse or outdoor hydroponic system. Seeds are placed into a styrofoam tray that has individual cells for each seed. Seeded trays are placed on fertilized water, and either a greenhouse or canvas/plastic is used for shelter.

d. Topping and Sucker Control

Topping tobacco at the proper time is a key management practice to ensure a high quality, high yielding crop. Topping stimulates root growth and increases yield through increased growth, as long as suckers are controlled. A tobacco plant produces a flower, and that growing apical tip inhibits the growth of lateral buds, which is also known as apical dominance (Yelverton, 1993).

Plant hormones play a role in plant growth and development. Auxins play a part in stem elongation and apical dominance. Cytokinin is known to influence cell division, cell and organ enlargement, and the delay of decline in flowers, vegetables and fruits. Gibberellins are important in elongation, bolting and flowering (Salisbury, 1992). When the flower is removed or "topped," lateral buds will elongate and grow. Tobacco will experience its largest increase in yield within 3 weeks following topping (Palmer, 1999).

Prior to or following topping, a sucker control chemical can be applied to control suckers and allow for proper leaf development. If suckers are >2.54 cm long at topping, they should be removed prior to application of sucker control. Three primary types of chemicals are currently available for sucker control 1) contacts, which kill small suckers by coming in contact with them and burning them, 2) systemics which restrict sucker growth physiologically without killing, and 3) contact-local systemics which must touch the sucker to be effective, although sucker growth is retarded by inhibition of cell division (Yelverton, 1993).

e. Harvest and Curing

Dr. Bill Maksymowicz, former University of Kentucky Tobacco Specialist, says that tests have shown burley tobacco buyers prefer tobacco harvested at 3-4 weeks after topping (Personal communication, 1999). Burley tobacco remaining in the field longer than 3-4 weeks receives little, if any yield advantage, leaving the crop susceptible to damaging weather and allowing more opportunity for disease to occur. Dark tobacco should be harvested 4-6 weeks after topping. Harvested plants are then taken to a barn or curing structure. Curing changes the physical and chemical properties of the leaf to make it suitable for market. Air movement, moisture, relative humidity and temperature are important parameters that influence curing. Placing tobacco too close together in the curing structure or not allowing enough air movement within the curing structure can cause houseburn. Houseburn occurs when the moisture level is high and causes tobacco to cure too slowly, producing darkened leaves, which lowers leaf quality (Duncan, 1990). However, too much air movement will cause tobacco to dry too rapidly and result in a mottled green leaf, also lowering leaf quality. Tobacco cures best if relative humidity is around 65-70% and if ambient temperature is in the range of 60-90°F (Duncan, 1990).

f. Weed Control

Weed control is an important production practice that must be considered prior to transplanting. First, one should identify what problem weeds are present. Once these pests are identified, one must decide which herbicide or herbicide combinations will provide the most cost-effective control. When considering herbicides, soil types in the fields must be identified since application rates and efficacy can be influenced by this and other soil characteristics such as organic matter content and pH. Most tobacco herbicides are labeled for pre-transplant application; a few products are labeled for post-transplant application. Weed interference can lower leaf yield and quality, increase production costs, interfere with harvesting operations, and increase spread of certain diseases. With the use of herbicides, the need for hand hoeing can be decreased or eliminated thus reducing the need for cultivation that in turn saves money and reduces soil erosion. Adequate weed control generally increases tobacco leaf yield by reducing weed competition for water, nutrients, and light.

With the advancements in chemical weed control, many problem weeds are effectively controlled with proper use of chemical control products.

Sulfentrazone provides effective control of many annual dicot species. Sulfentrazone is a selective, soil applied, herbicide that can be applied preemergence or shallow preplant incorporated. Weed roots and shoots readily absorb sulfentrazone, yet adequate rainfall or irrigation is necessary to activate the herbicide. Microbial degradation is considered the primary method of soil dissipation. Soil behavior is affected by both soil type and pH (Grey, et al., 1992). Soil types will vary the recommended rate of herbicide because of adsorptive properties. Rates are lower for soils with low clay and low organic matter because more of the herbicide is available in soil solution and control can be achieved with less active ingredient. However, soils with a high clay and organic matter content will adsorb more herbicide, and a more active ingredient will be needed to achieve adequate control.

Sulfentrazone reduces weed growth by inhibition of protoporphyrinogen oxidase, which effectively disrupts the enzyme system necessary for chlorophyll production. Most susceptible weeds die as they begin to emerge from the soil and others may die soon after exposure to light (C&P Press, 2001). Witt (1998) reported that ivyleaf morningglory control was greatest at the 0.56 kg/ha (8 ounces per acre) rate when lightly incorporated in the soil. Sulfentrazone plus pendimethalin, either incorporated or applied to the soil surface, provided >90 % control of *Setaria faberi* (giant foxtail), smooth pigweed, and ivyleaf morningglory. A soil surface applied treatment of sulfentrazone and clomazone provided >88% control of these three species. Some tobacco injury from sulfentrazone was noted four weeks after herbicide application, but injury was not apparent eight weeks after treatment (Witt and Slack, 1998).

Sulfentrazone may cause temporary stunting or yellowing of tobacco if transplants are placed too shallow or if heavy rainfall occurs immediately after transplanting. Splashing of treated soil onto tobacco leaves can cause burning of the contacted leaf area.

Clomazone provides effective control of grass weed species and control of certain broadleaf species. Clomazone controls susceptible species by inhibiting chlorophyll and carotenoid biosynthesis via inhibition of an enzyme in the isoprenoid pathway. Since emerging roots and shoots absorb clomazone, susceptible species emerging from treated soil lack pigmentation and plant death occurs shortly after emergence (Westberg et al., 1989). Command® 3ME is a microencapsulated clomazone formulation and serves to control the rate at which the active ingredient is released and becomes plant available. Clomazone can be applied preemergence, preplant incorporated or post transplant, within 7 days of transplanting.

Application rates need to be followed according to directions because over application may result in crop injury or soil residual. Excessive moisture, improper soil incorporation, uneven application, or deep planting can result in erratic weed control and/or crop injury. Adsorption of clomozone increases as soil pH decreases; therefore, soils with a pH of 6.0 or lower may promote greater potential for injury to monocot rotational crops (C&P Press, 2001). In field studies in Tennessee, clomazone dissipation in the soil was examined. The field half lives were 5 to 29 days in clay loam and Lily loam soils and 34 days under laboratory conditions (Kirksey, et al., 1996).

Sethoxydim is a selective, postemergence herbicide for the control of annual and perennial grass weeds in dicot crops. Sethoxydim rapidly enters the target weed through its foliage and translocates throughout the plant, achieving efficacy via interruption of lipid biosynthesis (C&P Press, 2001). Sethoxydim is most effective when applied to actively growing 10-20 cm (4-8 inch) grasses. If the grasses are under stress due to lack of moisture, herbicide injury, or flooding, unsatisfactory control may result. Sethoxydim degradation is enhanced by alkaline conditions, ultraviolet and incandescent light and adsorption on solid surfaces (Shoaf and Carlson, 1992). In Shoaf's experiment sethoxydim structural changes were studied in relation to how it interacts with water. No sethoxydim was detected soon after application to moist soil and less than 2% extractable sethoxydim was present in dry soils after one day (Shoaf, 1992).

Pendimethalin controls many annual grasses and certain broadleaf weeds as they germinate, but does not control established weeds. Pendimethalin acts as a mitotic inhibitor to effectively control susceptible species. Pendimethalin can be applied preplant incorporated and/or as a posttransplant lay by application and is most effective when adequate rainfall or irrigation is received within 7 days after application to carry the herbicide into the root zone of the germinating weeds. Unusually cold, excessively wet or hot and dry conditions that delay germination or extend germination over a long period of time can reduce weed control. Deep soil incorporation can also reduce weed control. Soil textures need to be considered when calculating application rates to increase control potential. Coarse soils (sands, loamy sands, sandy loams) need less of the herbicide and fine (silty clay loams, silty clays, clays, clay loams) soils need more of the herbicide to obtain the same efficacy. The half-life of pendimethalin under field conditions in turfgrass was 23-30 days and was not affected by application rate or rainfall treatment (Lee, et al., 2000).

Pendimethalin was tested at the University of Tennessee Agricultural Experiment Station as preplant incorporated applications at rates of 0.84, 1.13, 1.69 kg a.i./ha (0.75, 1.0, and 1.5 lb/acre) and as a preemergence application at 1.13 kg a.i./ha (1.0 lb/acre). A preplant incorporated application at the 0.84 kg a.i./ha (0.75 lb/acre) rate provided 90%

control of annual grasses, 100% control of *Mollugo verticillata* L. (carpetweed), and 89% control of pigweed. Increasing the rate to 1.0 lb/acre provided >90% control of both annual grasses and broadleaf weeds. The same application rates at a different experiment station resulted in 97% control of *Digitaria sanguinalis* (large crabgrass), 69% control of morningglory, and 55% control of pigweed. As a preemergence treatment pendimethalin at 1.13 kg a.i./ha (1.0 lb/acre) provided variable control of annual grasses and good to excellent control of selected broadleaved weeds (Rhodes, et al., 1983).

Napropamide controls seedling johnsongrass, panicums, redroot and smooth pigweed. Napropamide is applied preemergence, pre-plant incorporated and/or as a post transplant application. Lower rates are utilized on light, coarse-textured soil and the higher rate on heavy, fine textured soil, for best results, due to soil adsorptive characteristics. Napropamide is a long lasting chemical that is slowly broken down by microorganisms in the soil and has a half-life of 8-12 weeks in loam soils. Napropamide also can form soluble complexes with dissolved organic matter and Nelson performed a leaching study to evaluate the effect of a drying event following herbicide application. Results showed that less than 6% of the total herbicide applied moved by facilitated transport; the amount of rapidly mobile pesticide could increase the potential for contamination of groundwater. Results suggest that preventing the applied herbicide application from drying before irrigation could reduce or eliminate the threat of transport of napropamide by the dissolved organic matter. Therefore a short irrigation period or rainshower after herbicide application could reduce groundwater contamination by herbicide movement beyond the soil surface to deter drying while preventing deep movement of pesticide with the water front (Nelson, et al., 2000).

A preplant incorporated application of 3.38 kg/ha (3.0 lb/acre) gave >93% control of annual grasses and broadleaf weeds with the exception of *Brassica kaber* (mustard) that was controlled 78%. Napropamide applied at 1.13-2.25 kg/ha (1.0 to 2.0 lb/acre) gave excellent control of all annual grasses and broadleaf weeds except that control of henbit (*Lamium amplexicaule)* was only fair (Rhodes, et al., 1983).

Since one herbicide cannot alleviate all weed control problems, herbicide combinations are used to effectively control weed problems in tobacco fields. In research conducted by the University of Kentucky, combinations of herbicides were tested to observe weed efficacy in burley tobacco. Pendimethalin alone provided 93% morningglory control and 87% crabgrass control. An addition of sulfentrazone improved morningglory control to 100% and crabgrass control to 91%. A combination of clomazone and sulfentrazone was applied preplant and achieved 100% control of morningglory species and 99% control of crabgrass. A combination of sulfentrazone applied at preplant and clomazone 7 days post-transplant controlled morningglory 100% and crabgrass 80% (Palmer and Pearce, 2000).

Sulfentrazone combinations were studied in research at the University of Tennessee. Weed control using a sulfentrazone plus clomazone and a sulfentrazone plus pendimethalin combination were tested. Smooth pigweed, large crabgrass, Pennsylvania smartweed, carpetweed, and yellow nutsedge were controlled $\geq$ 90% (Breeden et al., 1999).

Even with all the chemical control products and combinations thereof, not all weeds can be controlled with one herbicide. Other weed management practices such as crop rotation, early root destruction, and cultivation can supplement a tobacco herbicide program. Some of the more difficult to control weeds in tobacco can be controlled via crop rotation (Worsham, 1992). Additionally, mechanical cultivation remains an effective weed management tool.

CHAPTER III

MATERIALS AND METHODS

Field research plots were established in 2000 at the Western Kentucky University Agricultural Research and Education Complex in Bowling Green, Kentucky. A randomized complete block design contained six treatments replicated three times in each of two crops (burley and dark-air cured tobacco). Prior to transplanting, burley hydroponic tobacco transplants (cv. 'TN 97') and dark air-cured tobacco transplants (cv. 'KY 160') were treated with imidacloprid at a rate of 7.3 g a.i. /1000 plants for insect control. Transplants were established on June 2, 2000 in a conventionally tilled Pembroke silt loam soil with a soil pH of 6.5 and organic matter content of 12 g/kg. Burley tobacco was transplanted with 107 cm row spacing and 56 cm in-row spacing. Dark air-cured transplants were established with 107 cm row spacing and 89 cm in-row spacing. Plot dimensions were 3.1 m wide by 9.1 m long.

Prior to crop establishment, 281.25 kg Nitrogen/ha (250 pounds N/acre) as NH_4NO_3, 56.25 kg P_2O_5/ha, 56.25 kg K_2O/ha as 6-24-24, and 337.5 kg/ha of pelletized lime were applied to the field. Herbicides treatments were applied on June 1, 2000 with a CO_2 backpack sprayer delivering 180 L/ha at 38 psi. Six treatments were applied to both the burley and dark-air cured plots. In each 4 row plot, treatments were applied to the 2 center rows, leaving the outer rows for comparison purposes. Treatments are described in Table 1.

Table 1. Herbicide Treatments

Treatment	Product	Application rate Kg ai ha $^{-1}$	Application Timing
1	sulfentrazone	0.354 kg a.i. $^{-1}$/ha	PREPLANT
2	sulfentrazone	0.354 kg a.i. $^{-1}$/ha	PREPLANT
	clomazone	0.628 kg a.i. $^{-1}$/ha	PREPLANT
3	sulfentrazone	0.354 kg a.i. $^{-1}$/ha	PREPLANT
	pendimethalin	0.93 kg a.i. $^{-1}$/ha	PREPLANT
4	sulfentrazone	0.354 kg a.i. $^{-1}$/ha	PREPLANT
	napropamide	1.12 kg a.i. $^{-1}$/ha	PREPLANT
5	sulfentrazone	0.354 kg a.i. $^{-1}$/ha	PREPLANT
	clomazone	0.628 kg a.i. $^{-1}$/ha	PREPLANT
	followed by		
	sethoxydim	0.314 kg a.i. $^{-1}$/ha	POSTPLANT
	non-ionic surfactant	0.25% v/v	POSTPLANT
6	clomazone	0.628 kg a.i. $^{-1}$/ha	PREPLANT
	pendimethalin	0.93 kg a.i. $^{-1}$/ha	PREPLANT

The fungicide mefenoxam labeled as Ridomil Gold® at 0.56 kg ai ha^{-1} was added to each treatment.

Visual evaluations of crop injury were made 14, 21, and 28 days after treatment (DAT). Evaluations of crop injury were based on a scale of 0 to 100%, 0% representing no apparent injury and 100% representing crop death. Visual evaluations of weed control were taken at 21, 28, 42, and 56 DAT for ivyleaf morningglory, smooth pigweed, and goosegrass. Weed control ratings were made using a visual scale of 0 to 100% with 0% representing no control and 100% representing complete control. Visual observations were taken from the center of each plot.

Data were subjected to ANOVA and means were separated with Duncan's Multiple Range Test (MRT) test at the 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

Ivyleaf morningglory control in burley tobacco with sulfentrazone alone was ≥89 % at all evaluation dates (Table 2); control was 93% 56 DAT with no signs of crop injury. Addition of clomazone, pendimethalin, napropamide did not improve control of ivyleaf morningglory, which is what was expected based on previous data, since sulfentrazone provides excellent control of ivyleaf morningglory. Sulfentrazone plus pendimethalin showed ≥95% control on all evaluation dates. Combinations of sulfentrazone, clomazone and sethoxydim provided ≥ 88% morningglory control 21 and 28 DAT but control decreased to 76% 56 DAT. Clomazone + pendimethalin provided ≥90 % control at all evaluation dates. Therefore, according to the data, it would not be necessary for farmers to tank mix with other herbicide combinations for effective control of ivyleaf morningglory.

In the dark air-cured tobacco plot, results were similar to the burley plot. Ivyleaf morningglory control with sulfentrazone alone was ≥95 % at all evaluation dates, which was not different from other treatments. Sulfentrazone plus clomazone provided ≥91% control at all evaluation dates (Table 3). The sulfentrazone and napropamide treatment gave ≥94% control. Clomazone plus pendimethalin was 90% effective in controlling morningglory 22 and 28 DAT, yet by 56 DAT control decreased to 67%.

Smooth pigweed control in burley tobacco with sulfentrazone was 81% at 21 DAT and decreased to 75% control 56 DAT (Table 4). The sulfentrazone and clomazone combination provided 62.5% control 21 DAT, but this control level was to be expected

Table 2: Ivyleaf morningglory control and crop injury in burley tobacco as influenced by herbicide combinations*

TREATMENT	Weed Control ------------------------------%-------------------------				Crop Injury
	21 DAT**	28 DAT	42 DAT	56 DAT	14, 21, 28 DAT
1 sulfentrazone	89.3 a	96.7 a	92.0 a	92.7 a	0
2 sulfentrazone/clomazone	88.3 a	81.0 a	87.7 a	87.7 a	0
3 sulfentrazone/pendimethalin	96.3 a	95.0 a	95.0 a	95.7 a	0
4 sulfentrazone/napropamide	93.0 a	93.7 a	93.0 a	93.3 a	0
5 sulfentrazone/clomazone/sethoxydim	90.0 a	88.0 a	89.3 a	76.0 a	0
6 clomazone/pendimethalin	91.7 a	92.7 a	91.0 a	90.7a	0
LSD (0.05)	12.9	19.9	11.9	27.6	

*means sharing the same letter are not significantly different (∝=0.05)
**DAT=Days after treatment

Table 3. Ivyleaf morningglory control and crop injury in dark-air cured tobacco as influenced by herbicide combinations*

TREATMENT	Weed Control --------------------------------%------------------------------				Crop Injury
	21 DAT**	28 DAT	42 DAT	56 DAT	14, 21, 28 DAT
1 sulfentrazone	97.7 a	97.3 a	96.3 a	95.7 a	0
2 sulfentrazone/clomazone	94.0 a	93.3 a	91.0 a	91.7 a	0
3 sulfentrazone/pendimethalin	96.7 a	96.0 a	95.7 a	95.7 a	0
4 sulfentrazone/napropamide	97.3 a	96.7 a	94.3 a	95.3 a	0
5 sulfentrazone/clomazone/sethoxydim	97.5 a	96.5 a	97.0 a	95.7 a	0
6 clomazone/pendimethalin	90.0 a	95.0 a	78.0 a	67.0 a	0
LSD (0.05)	7.8	3.7	21.3	33.8	0

*means sharing the same letter are not significantly different (∝=0.05)
**DAT=Days after treatment

Table 4. Smooth Pigweed control and crop injury in burley tobacco as influenced by herbicide combinations*

TREATMENT	Weed Control --------%--------				Crop Injury
	21 DAT**	28 DAT	42 DAT	56 DAT	14, 21, 28 DAT
1 sulfentrazone	81.3 ab	74.0 a	69.0 a	75.7 a	0
2 sulfentrazone/clomazone	62.5 b	80.0 a	85.0 a	78.3 a	0
3 sulfentrazone/pendimethalin	90.0 a	94.0 a	95.7 a	92.7 a	0
4 sulfentrazone/napropamide	81.7 ab	90.0 a	81.0 a	84.3 a	0
5 sulfentrazone/clomazone/sethoxydim	88.0 a	76.0 a	66.0 a	73.3 a	0
6 clomazone/pendimethalin	90.0 a	92.5 a	90.7 a	83.3 a	0
LSD(0.05)	22.9	37.1	41.2	27.1	

*means sharing the same letter are not significantly different (∝=0.05)
**DAT=Days after treatment

since clomazone is most effective on grasses. However, control improved to ≥78% 56 DAT, possibly due to rainfall received that helped re-activate the herbicide. Sulfentrazone plus pendimethalin provided ≥90% control on all evaluation dates. The sulfentrazone and napropamide combination provided ≥81% control of smooth pigweed. The combination of sulfentrazone, clomazone and sethoxydim gave 88% control at the first evaluation date yet decreased to 76% and 73% at 28 and 56 DAT, respectively. The clomazone and pendimethalin combination provided 90% and 93% control at 22 and 28 DAT. The combinations of sulfentrazone and pendimethalin, sulfentrazone, clomazone and sethoxydim, and clomazone and pendimethalin provided better control of smooth pigweed 21 DAT than did sulfentrazone plus clomazone, but there were no differences among treatments at later evaluation dates. According to the data, there would be no advantage to using clomazone in a tank mix for smooth pigweed control.

Smooth pigweed control in dark air-cured tobacco with the sulfentrazone treatment alone was ≥85% at all evaluation dates (Table 5). At 21 DAT control was 96% and decreased thereafter. Sulfentrazone plus clomazone controlled smooth pigweed 91% 21 DAT and 88% 28 DAT, but decreased to 68% 56 DAT. The sulfentrazone and pendimethalin treatment controlled smooth pigweed 91% 21 DAT and 88% 28 DAT but decreased to 82% 56 DAT. The sulfentrazone and napropamide combination had ≥ 92% control at the first two evaluation dates, but decreased to 83% 56 DAT. The sulfentrazone, clomazone, and sethoxydim treatment resulted in only 68% control at 21

Table 5. Smooth Pigweed control and crop injury in dark-air cured tobacco as influenced by herbicide combinations*

TREATMENT	Weed Control --------------------%--------------------				Crop Injury
	21 DAT**	28 DAT	42 DAT	56 DAT	14, 21, 28 DAT
1 sulfentrazone	96.0 a	88.7 a	90.7 a	85.7 a	0
2 sulfentrazone/clomazone	91.0 ab	87.7 a	78.3 a	68.3 a	0
3 sulfentrazone/pendimethalin	91.7 ab	88.3 a	87.7 a	82.0 a	0
4 sulfentrazone/napropamide	93.7 a	92.7 a	88.0 a	83.3 a	0
5 sulfentrazone/clomazone/sethoxydim	68.3 b	85.0 a	73.3 a	52.7 a	0
6 clomazone/pendimethalin	90.0 ab	91.7 a	87.7 a	86.0 a	0
LSD (0.05)	23.2	12.4	20.9	42.7	0

*means sharing the same letter are not significantly different (∝=0.05)
**DAT=Days after treatment

DAT and then increased to 85% 28 DAT and decreased again to 53% control 56 DAT. Perhaps the results were varied due to lack of target weed pressure in the plot and/or undesirable weather conditions. Clomazone plus pendimethalin controlled smooth pigweed at $\geq$86% at all evaluation dates. At 21 DAT sulfentrazone and sulfentrazone and napropamide gave better control than did sulfentrazone, clomazone, and sethoxydim, but there were no significant differences at later evaluation dates.

Goosegrass control in burley tobacco with sulfentrazone alone was >60% at 22 and 28 DAT, then dropped to 45% at 42 DAT, but increased to 70% at 56 DAT showing no signs of crop injury (Table 6). The increase of control could be due to rainfall received in that time period. Since sulfentrazone is readily absorbed by the roots and shoots, moisture is necessary to activate the herbicide. Addition of other herbicides improved goosegrass control at all evaluation dates. The sulfentrazone and clomazone combination provided >89% control at all evaluation dates. The combination of sulfentrazone and pendimethalin provided >94% control at all evaluation dates. This data supports previous research in which sulfentrazone provided better goosegrass control when applied in a tank mix with clomazone, pendimethalin, napropamide, or clomazone/sethoxydim (Kelley, 2000). In the case of goosegrass, sulfentrazone alone would not be a good option for long-lasting goosegrass control. However, if a field had broadleaf weed pressure along with goosegrass pressure a sulfentrazone combination may be a good option.

In dark-air cured tobacco, results were similar to the burley tobacco. Sulfentrazone treatment controlled goosegrass >86% at all evaluation dates (Table 7).

Table 6. Goosegrass control and crop injury in burley tobacco as influenced by herbicide combinations*

TREATMENT	Weed Control ----------%----------				Crop Injury
	21 DAT**	28 DAT	42 DAT	56 DAT	14, 21, 28 DAT
1 sulfentrazone	60.0 b	62.3 b	45.0 b	70.0 b	0
2 sulfentrazone/clomazone	91.5 a	96.5 a	93.0 a	89.0 a	0
3 sulfentrazone/pendimethalin	96.0 a	95.0 a	94.3 a	96.7 a	0
4 sulfentrazone/napropamide	86.7 ab	91.0 a	96.3 a	95.7 a	0
5 sulfentrazone/clomazone/sethoxydim	94.3 a	94.0 a	98.3 a	98.3 a	0
6 clomazone/pendimethalin	96.0 a	94.0 a	90.3 a	96.3 a	0
LSD (0.05)	28.2	27.8	21.0	14.0	

*means sharing the same letter are not significantly different ($\propto$=0.05)

**DAT=Days after treatment

Table 7. Goosegrass control and crop injury in dark-air cured tobacco as influenced by herbicide combinations*

TREATMENT	Weed Control ----------%----------				Crop Injury
	21 DAT**	28 DAT	42 DAT	56 DAT	14, 21, 28 DAT
1 sulfentrazone	90.7 a	87.3 b	86.0 b	88.3 b	0
2 sulfentrazone/clomazone	96.0 a	97.3 a	94.7 a	95.0 a	0
3 sulfentrazone/pendimethalin	97.7 a	97.7 a	94.3 a	95.0 a	0
4 sulfentrazone/napropamide	92.5 a	91.7 b	92.7 ab	93.3 ab	0
5 sulfentrazone/clomazone/sethoxy dim	97.0 a	98.3 a	97.7 a	99.0 a	0
6 clomazone/pendimethalin	97.7 a	97.3 a	95.7 a	94.0 ab	0
LSD (0.05)	7.2	5.4	6.7	5.6	

*means sharing the same letter are not significantly different (∝=0.05)

**DAT=Days after treatment

Sulfentrazone alone provided 91% control of goosegrass at 21 DAT, but control decreased at later evaluation dates. With the exception of napropamide, addition of other herbicides to sulfentrazone improved goosegrass control at 28 and 42 DAT. At 56 DAT the combinations of sulfentrazone/clomazone, sulfentrazone/pendimethalin and sulfentrazone/clomazone/sethoxydim provided better control of goosegrass than other herbicide combinations.

With the results of this study, farmers need to evaluate their weed presence and then choose the proper combination to effectively control the weeds present. For instance, if a farmer had a morningglory problem alone, sulfentrazone would be the best control option. However, if it was a drought year, control may be sporadic or ineffective due to lack of moisture. However, if grass were the problem in a field sulfentrazone alone would not be the herbicide of choice. It would be more effective to use clomazone and pendimethalin alone or in herbicide combinations. If the grasses are already present sethoxydim may be the herbicide of choice. Yet, with any herbicides or herbicide combinations, factors such as lack of or excessive rainfall, pH levels, and weather conditions can result in erratic weed control and crop injury. Other factors such as uneven application, deep planting, pre- or post-application, application rates and soil composition can also have an effect on control of weeds.

CHAPTER V

CONCLUSION

Although there is no one herbicide that will control all weed species, combinations of herbicides can provide effective control of many weed species under normal growing conditions.

Sulfentrazone alone provided $\geq$ 85% weed control of smooth pigweed in dark-air cured tobacco and >69% control of smooth pigweed in burley tobacco. Sulfentrazone provided $\geq$ 89% control of ivyleaf morningglory in burley and $\geq$95% control in dark-air cured tobacco. Addition of other herbicides did not improve ivyleaf morningglory control or pigweed control. Goosegrass control was $\geq$97% in dark air cured with the triple combination of sulfentrazone/clomazone and sethoxydim and the same treatment provided $\geq$94.0% control in burley tobacco at all evaluation dates. Addition of other herbicides improved goosegrass control at all evaluation dates. This data would suggest that producers could benefit by adding clomazone or napropamide to sulfentrazone in a tank mix to provide better goosegrass control.

There were few differences in control of smooth pigweed with all herbicide treatments in burley and dark-air cured tobacco. In burley tobacco, sulfentrazone/pendimethalin, sulfentrazone/clomazone/sethoxydim and clomazone/pendimethalin combinations provided better smooth pigweed control 21

DAT than other combinations. In dark air-cured tobacco at 21 DAT, sulfentrazone and sulfentrazone/napropamide provided better control of smooth pigweed than other herbicide combinations, but showed no differences at later evaluation dates. Therefore, if smooth pigweed were the only weed in the field, it would not be beneficial for the farmer to use any combination except sulfentrazone alone.

Although there was not any one herbicide combination that was most effective on all weeds, combinations can be tailored to provide broad-spectrum control of these weed species. However, proper land preparation, crop rotation, and timely post transplant cultivation should also be used with these herbicides for maximum weed control.

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